

Effect of Particle Damping on an Acoustically Excited Curved Vehicle Panel Structure with varied Equipment Assemblies

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Particle dampers provide a mechanism for diverting energy away from resonant structural vibrations. This experimental study provides data from trials to determine how effective use of these dampers might be for equipment mounted to a curved orthogrid vehicle panel. Trends for damping are examined for variations in damper fill level, component mass, and excitation energy. A significant response reduction at the component level would suggest that comparatively small, thoughtfully placed, particle dampers might be advantageously used in vehicle design. The results of this test will be compared with baseline acoustic response tests and other follow-on testing involving a range of isolation and damping methods. Instrumentation consisting of accelerometers, microphones, and still photography data will be collected to correlate with the analytical results.

Nomenclature

ESTS = Engineering, Science, and Technical Services
MSFC = Marshall Space Flight Center
NESC = NASA Engineering and Safety Center

I. Introduction

Highly energetic structural responses of lightly damped aerospace structures to acoustic fields present significant problems for the survivability of electronic equipment and the structural integrity of structural members. For these structures, even a slight increase in available damping at the right location, could make a critical difference, by reducing the response at resonance. Validating vibration environments estimates for equipment assembled to vehicle panels and refining analytical approaches used to estimate these environments, based on ground or flight tests, is of major importance to new vehicle programs. The data from this experimental series should permit critical evaluation of the usefulness of particle dampers and suggest estimation methodology useful to the aerospace community.

Marshall Space Flight Center (MSFC) completed a series of ground test cases using acoustic noise to excite a flight-like vehicle panel during December 2010. Follow on tests are now under way that are intended to illustrate

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differences in damping that may be expected when particle dampers are added to the configurations under test. This paper will report on the damping trends observed from response measurements for several different test configurations and varying particle damper fill levels. As well as answering the question of efficacy, the test has been designed to investigate the variation with excitation energy and the ratio of particle mass to component mass. Since the very configurations and levels under test are also being subjected to other damping/isolation methods, the collected data should inform analysts as to the relative merits of these methods.

II. Test Overview

The flight like test article used in acoustic ground testing at MSFC is constructed as an aluminum orthogrid rib stiffened panel. It has a curved outer mold line that approximately represents a 45^0 section comprising $1/8^{\text{th}}$ of the cylindrical exterior shell of a launch vehicle. The panel is clamped in a baffled condition separating the reverberant chamber from an anechoic room (i.e. a flight like condition where the exterior side of the panel is excited by the high energy acoustic field). The panel is subjected to acoustic noise excitation energies simulating the liftoff and more roughly approximating the ascent flight events. Note that fixing the baffled panel so that it is excited by source room energies on one side only, approximates the loading in service on the launch vehicle. Accelerometer, microphone, and strain gage data recorded the response of the panel as well as the transmission loss.

The acoustic field was generated in the MSFC Reverberant Chamber using conditioned air which was driven using up to four parallel WAS 3000 Modulators which feed sound into the room through a single horn. The acoustic field will be monitored using an array of microphones in front of the test article. The standard configuration of microphones was to center them in each of six sectors 30 inches in front of the test article. This acoustic power source was utilized to approximate a diffuse acoustic field in a reverberant chamber. A sketch of the test chamber showing the source and receiver rooms set up with the approximate location of the microphone sensor array is presented as Figure 1.

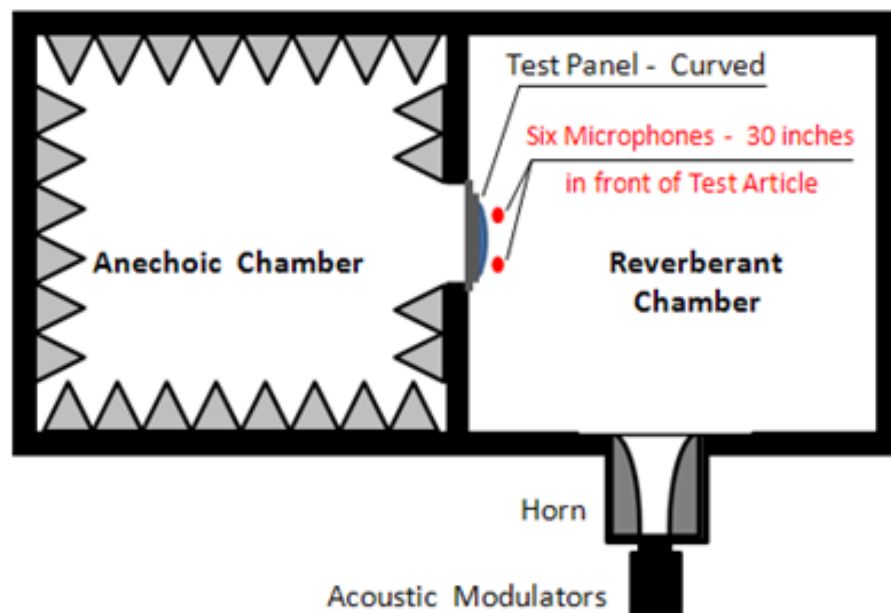


Figure 1. Test Chamber Plan View.

The panel has a smooth outer surface with small orthogrid construction on the interior surface. The material type is an aluminum 2219 alloy. It is approximately 81 inches in height. The outer surface is described by a diameter of 216.5 inches. The arc length is approximately equivalent to one eighth of the full cylinder circumference, which is approximately 85 inches. Pictures of the reverberant chamber showing the outer surface and the anechoic chamber showing the interior surface is presented as Figure 2 and Figure 3.



Figure 2. Reverb-Side Integration of Test Article.

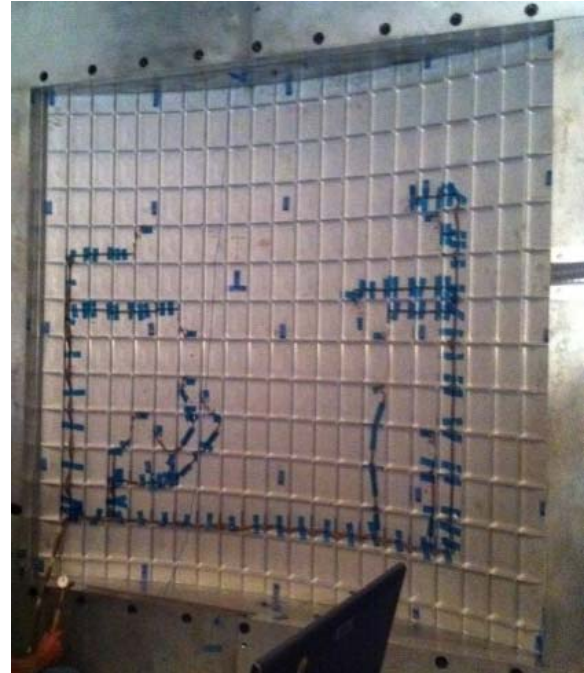


Figure 3. Anechoic-Side Integration of Test Article.

III. Test Configurations

Configurations for the test series include mass simulators that can be added to the orthogrid panel. During the original rounds of testing, three major configurations were explored; bare panel, variations based on a small mass simulator, and variations based on a larger (28" x 36") mass simulator. For the particle damping test series, the larger mass simulator was used. The basic configurations include:

1. Bare panel without particle dampers
2. Panel with brackets and 4 particle dampers
3. Panel with brackets, large mass simulator, and 4 particle dampers
4. Panel with brackets, large mass simulator, one mass increment plate, and 4 particle dampers

A picture of the large mass simulator configuration is presented in Figures 4. Particle damper installation and assembly details can be seen in Figures 5 and 6.

Within each basic test configuration, the fill level of the particle dampers was set to 0%, 30%, 60%, and 90% full. Particle (steel shot) fill was achieved via an opening at the top of the damper housing, which was sealed via a bolt. Additionally, each basic configuration, at each fill level, was exposed to four excitation levels wherein data was taken and recorded.

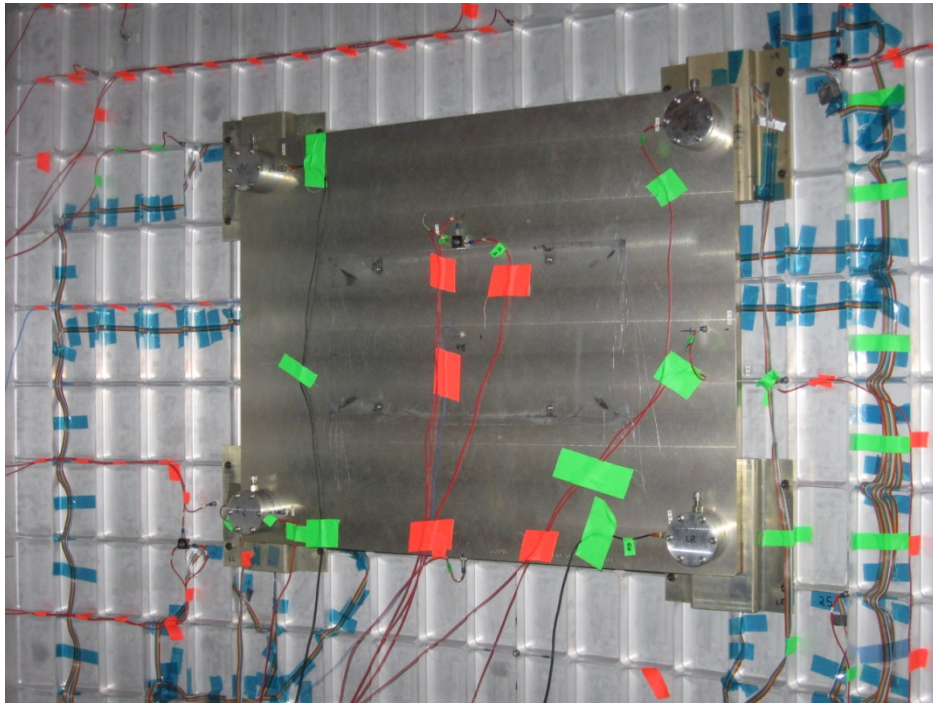


Figure 4. Anechoic-Side Integration of Test Article.

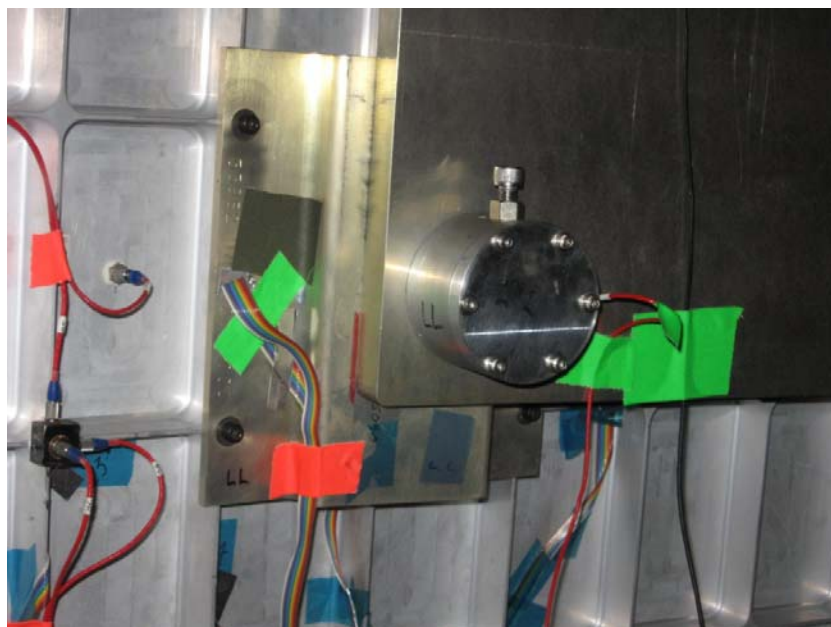


Figure 5. Installed Particle Damper on Mass Simulator

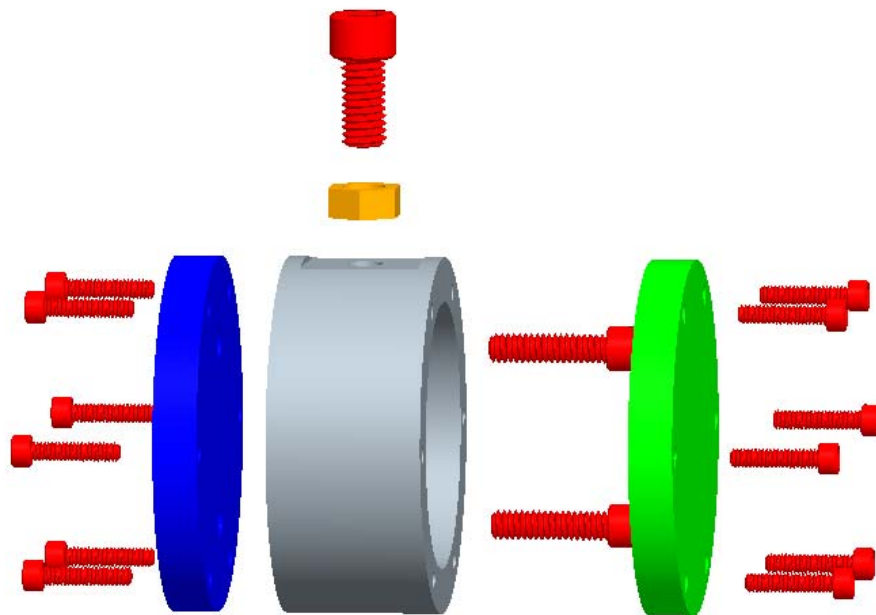


Figure 6. Particle Damper Assembly

IV. Supporting Characterization of Measurements

MSFC has used this test set up to produce significant sound pressure levels that elicit flight like levels of response in the test article system. Figure 7 shows a plot of the average sound pressure spectrum recorded by the six microphones in the reverberant chamber. Figure 8 presents response level for 5 configurations of the test article hardware that were tested without particle dampers. These serve as a baseline response which will help to illustrate the attenuation of response provided when the particle dampers are included during the follow on test series.

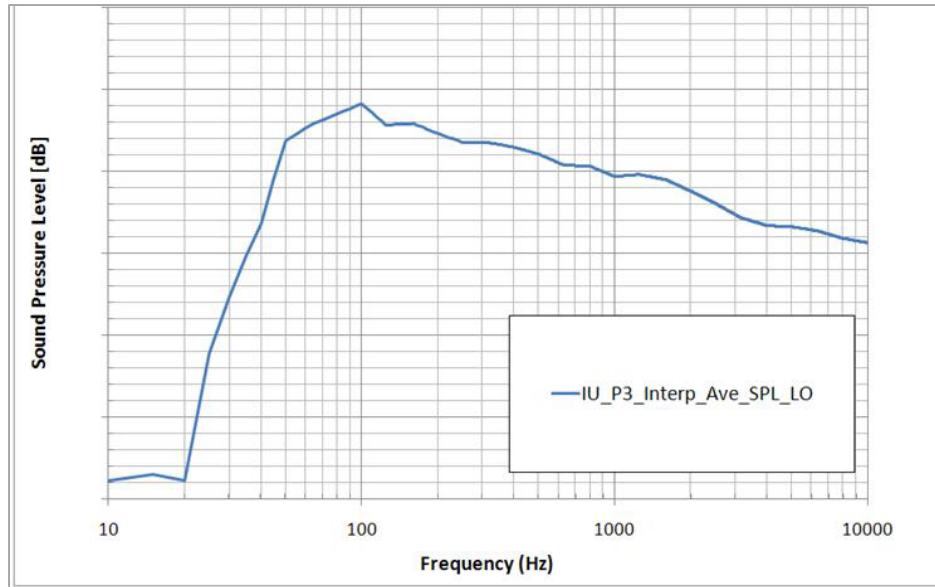


Figure 7. Example Average Liftoff Sound Pressure Level Repeated for Configurations with/without Particle Dampers.

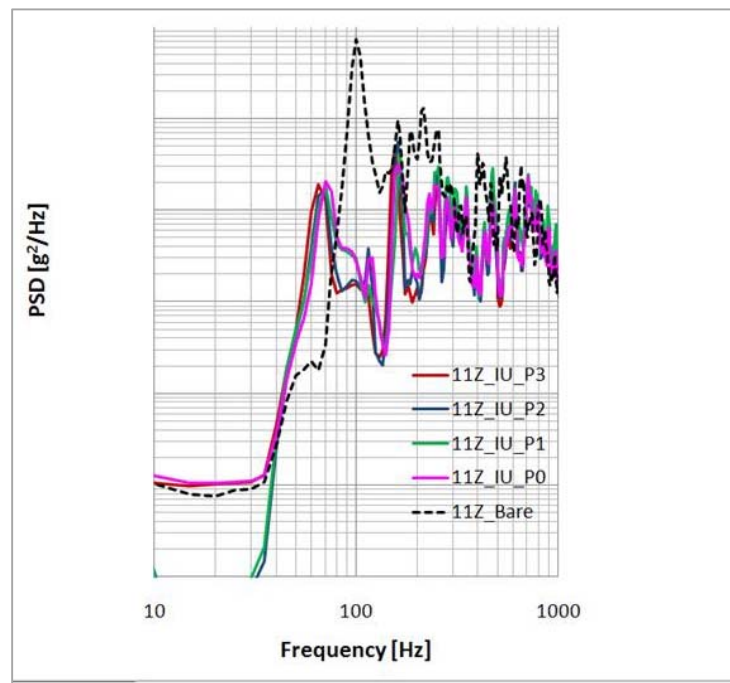


Figure 8. Reference Vibration Levels Prior to Addition of Particle Dampers- Response for Liftoff Acoustic Spectrum

V. Conclusions

The results of this development test will examine the effect of particle damping on the vibro-acoustic response of a mounted panel and the surrounding support structure to the specified acoustic environments. The test data obtained will be used as a point of reference for different methods of reducing vibro-acoustic response.

Acknowledgments

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